RESEARCH HIGHLIGHTS

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WATER PENETRATION RESISTANCE OF WINDOWS - STUDY OF CODES, STANDARDS, TESTING, AND CERTIFICATION

Introduction

Over the past decade there has been an increasing number of reports of moisture related performance problems in multi-unit residential buildings, particularly in British Columbia. This study addresses water penetration issues associated with windows in the context of codes, standards, testing and certification processes. It is considered to be one element in a process that will help the construction industry understand the factors that influence water penetration behaviour of window-to-wall interfaces, and more consistently result in installed windows that perform well over the course of their anticipated service lives. The study includes windows and water penetration issues associated with both low-rise wood frame buildings and high-rise non-combustible buildings. It also includes window-wall technology, but does not include curtainwall technology. A companion project (Water Penetration Resistance of Windows – Study of Manufacturing, Building Design, Installation and Maintenance Factors) to this study addresses water penetration issues in the context of the physical causal factors leading to water penetration and the impact that various industry sectors can have in influencing performance.

The study has three primary objectives:

1. To identify and document how existing codes, standards, testing and certification processes address in-service water penetration resistance of windows.
2. To critique these documents and processes in the context of the findings of the companion study regarding the primary causes of leakage associated with windows.
3. To develop recommendations regarding improvements that can be made to codes, standards and certification processes with respect to in-service water penetration performance.

Methodology

The methodology of this study is closely related to the companion study in which the prevalent causes of particular leakage paths were established. Based on the established leakage paths and causal factors, a large number of laboratory and field tests, as well as common codes, standards, certification processes, were reviewed.

The methodology involved a series of steps:

1. Identification of the major issues related to water penetration resistance of windows based on the results of the companion project;
2. Review of the results of more than 200 laboratory and field tests of windows to further establish the major issues related to water penetration resistance of windows, and to establish differences between laboratory and field testing protocols;
3. Review of applicable codes, standards and certification requirement to establish how they address the major water penetration issues;
   - National Building Code of Canada (NBC 1995)
   - Canadian window standards (A440, A440.1, A440.4)
   - North American Fenestration Standard (NAFS)
   - CSA Windows and Doors Certification Program
   - CCMC Evaluation of Doors and Windows
   - Window Wise Certification Program

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4. Development of recommendations for codes, standards, testing, certification and harmonization of North American standards with respect to the major water penetration issues.

Table 1: Overview of Codes, Standards and Certification Processes Reviewed

Building Codes	Standards	Certification
Canadian building codes (adopted at provincial or local levels) – sets out minimum provisions and requirements for windows in buildings. Makes reference to requirements set out in CSA A440[7].	Canadian Standards Association (CSA) A440[7] – sets out classification levels and test requirements for windows, with authority having jurisdiction assigning minimum levels to be met. Refers to ASTM testing standards. A440.1[8] User Selection Guide – how to select correct minimum levels and op-tion-al require-ments. A440.4–98[9] Installation Guide – sets out methods and minimum require-ments for both new installation and replacement install-ation of factory-assembled windows. Proposed North American Fenestration Standard[14] – would combine/replace U.S. standards and CSA A440[7] Windows. Sets out window classes and types, performance requirements and product designations.	CSA Windows & Doors Certification Program -(voluntary) certification granted on basis of meeting CSA A440 standards. Manufacturers obtain third-party assessment of their products to obtain this certification. Canadian Construction Materials Centre (CCMC) Doors and Windows Evaluation Program – voluntary performance-based program to establish conformance to applicable codes and standards, including Canadian building code and CSA A440[7]. Testing performed by laboratories recognized by CCMC. Evaluation product listing provided to the public. Window-Wise Certification Program - managed by the Siding and Windows Dealers Association of Canada to certify window installers in the replacement of window field (not applicable to new construction). Windows must be to CSA A440[7] standard, and mandatory installation program based on A440.4[9] standard.

The study analysed the results of 113 laboratory and 127 field tests of windows. The test results include standardized tests from a window test facility, field quality assurance tests during construction, general condition assessment testing to confirm in-service performance, and tests conducted as part of an investigation of known leakage problems. The tests were not carried out specifically for the study and therefore many reports were not structured in a consistent manner. Evaluators were required to use judgment in comparing and analyzing results.

Data from test results was compiled using a standard format. The first section of the data collection form documents the testing agency, date of test, and type of window tested. Sections 2 and 3 are applicable to lab and field tests respectively and describe the type of test, and reason for test. In the case of field tests information on the building type was also recorded. Section 4 of the form contained key information related to test specimen description, leakage paths, causal factors and test pressures.

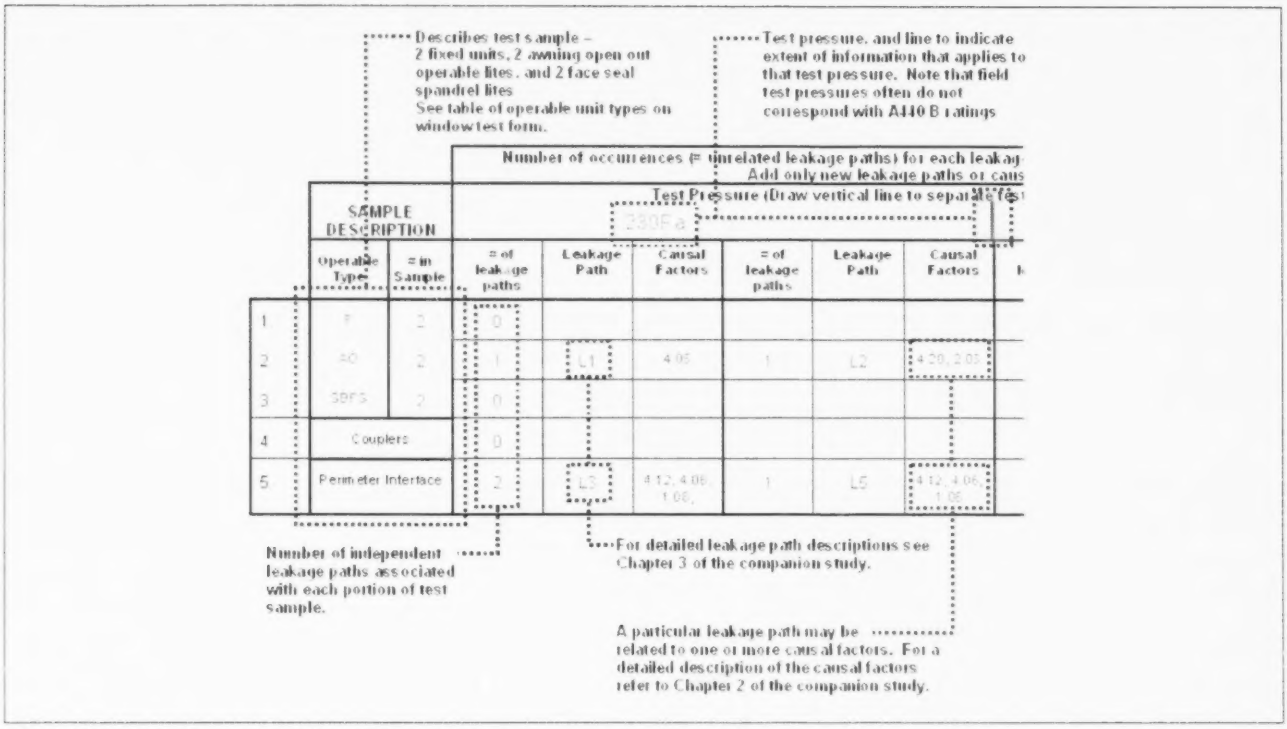
Describes test sample –
2 fixed units, 2 awning open out operable lites, and 2 face seal spandrel lites
See table of operable unit types on window test form.
Test pressure, and line to indicate extent of information that applies to that test pressure. Note that field test pressures often do not correspond with A440 B ratings
Number of occurrences (# unrelated leakage paths) for each leakag
Add only new leakage paths or caus
Test Pressure (Draw vertical line to separate test
SAMPLE DESCRIPTION
Operable Type
in Sample
of leakage paths
Leakage Path
Causal Factors
# of leakage paths
Leakage Path
Causal Factors
1
2
3
4
5
Couplers
Perimeter Interface
L1
L2
L5
4.05
4.12, 4.06, 1.06,
4.20, 3.05
4.12, 4.06, 1.06
Number of independent leakage paths associated with each portion of test sample.
For detailed leakage path descriptions see Chapter 3 of the companion study.
A particular leakage path may be related to one or more causal factors. For a detailed description of the causal factors refer to Chapter 2 of the companion study.

Figure 1 Section 4 of Test Data Collection Form, including explanatory text.

Water Penetration Test Result Analysis

Analysis of the data compiled from the 240 tests generated some key observations:

1. There are far fewer failures in the lab testing than the field testing (79 vs. 215)

   This is to be expected given that lab testing typically tests a new window that has not been installed, and has been carefully made for the purpose of testing. In addition, the lab test does not test for leakage at the interfaces, while the field test does.

2. There are far fewer significant leakage paths in the lab testing (1) than the field testing (6)

   This is also an expected result. Primarily the lab testing identifies water leakage though the operable windows as being the largest problem. This is typical for the lab test since leakage path L1 (through fixed unit to interior) is typically well sealed prior to testing, leakage paths L3 and L5 (through wall interface to interior or wall assembly) are excluded from the lab testing, L4 (through window assembly to wall assembly) is not always checked during the lab test, and L6 (through window assembly to concealed compartments within window assembly) is generally a less frequently occurring path and is not always easily verified.

3. There are many more causal factors identified in the field testing (27) than the lab testing (6)

   This is likely due to several factors, some of which are discussed above. In addition, windows that have been field-tested have been manufactured on an assembly line instead of possibly being specifically made for testing. In addition, windows have been transported to site, moved numerous times prior to installation, all of which can put stress on sealants and gaskets. Windows have also been exposed to weathering forces such as water, temperature fluctuations, and UV light that can have an adverse effect on sealants and gaskets. Finally, many causal factors identified in this section are related to the installation of the window and these would have been excluded from the results in the lab test.

Review of Codes, Standards and Certification Processes

National Building Code of Canada (NBC 1995), Part 5

Strengths

- The code requires that materials and assemblies are resistant to deterioration by reasonable expected mechanisms. Window leakage that would result in damage to other assemblies is clearly not permitted to occur (5.1.4.2., 5.6.1.1.)
- Appendix A to the code provides guidance with respect to service life considerations.
- Interfaces between assemblies must be designed to prevent water penetration (5.6.2.1., 5.6.2.2.)
- Appendix A identifies the difficulty in achieving a perfect surface-sealed barrier (face seal).

Limitations

- Although the code identifies the need to consider exterior environmental loads, it does not explicitly acknowledge the micro-climatic effects of building form and topography, which impact on the frequency and time of wetness due to rain.
- The code does not provide any guidance on the design and selection of appropriate water penetration control strategies for various exposure conditions.

National Building Code of Canada (NBC 1995), Part 9

Strengths

- Article 9.7.2.1 requires compliance to the minimum requirements of the appropriate window standards, CSA A440[7] and CSA A440.1[8]. The associated appendix note identifies the need to consider the A440.1[8] User Selection Guide to select windows for a particular site.
- The code indicates an understanding and explicit recognition that overhangs can have an impact on building exposure conditions (9.20.13.3 and 9.27.3.2.2.)

Limitations

- Part 9 does not acknowledge the fact that the rain exposure conditions for smaller Part 9 buildings can be as significant as for many larger Part 5 buildings. Walls and windows of Part 5 and Part 9 buildings can have identical, and sometimes high, exposure conditions and should be designed accordingly.
- Part 9 does not acknowledge the micro climate effects of building form, and local topography which impact on the frequency and time of wetness due to rain.
- Part 9 provides no guidance on design and selection of appropriate water penetration control strategy.

CSA A440-00 Window Standards

The A440 series of window standards and special publications provides a set of performance oriented and prescriptive requirements for all factory built windows. Of particular relevance to water penetration control are standard CSA A440-00[7] Windows, special publication CSA A440.1-00[8] User Selection Guide to CSA Standard A440-00, Windows and standard CSA A440.4-98[9] Window and Door Installation.

Strengths

- Provides a consistent basis for the evaluation of water penetration performance.
- Provides for different water penetration resistance levels.
- References an established lab test protocol (ASTM E547) so that the results of testing are comparable and repeatable.
- The User Selection Guide provides a rational basis for selection of test pressure differential based on climatic data for specific geographic locations and building height.
- The Installation standard represents a first attempt at integrating and ensuring continuity of critical barriers, and installation requirements at the interface between the window and adjacent wall assemblies.
- The installation standard provides some sound fundamental principles for water penetration control associated with the interface between the window and the wall.

Limitations

- The CSA A440 standard is intended for the evaluation of manufactured components and therefore does not consider water penetration resistance of installed window assemblies.
- The standard does not generally consider the durability of water penetration resistance of the window assembly.
- The standard does not consider the performance of combination windows such as strip windows or window wall assemblies.
- It is not clear that there is any rational basis for the use of DRWP (Driving Rain Wind Pressure) as the primary factor for establishing a rating system for effective water penetration control. In addition the

use of the 1 in 5 DRWP criteria for small buildings vs. 1 in 10 DRWP criteria for larger buildings does not reflect the reality of high exposure conditions that can occur with many buildings that are considered 'small' in NBC-95[11].

- The guide utilizes climate data for a particular elevation above the ground level. While this may be appropriate for simple low rise structures set on simple sites, it is not appropriate for more complex potentially higher pressure regimes associated with high-rise buildings or with low-rise buildings situated on exposed sites.
- The installation standard currently provides a great deal of guidance and examples with respect to performance issues such as air tightness and support of glazing units and disproportionately few examples illustrating the principles of water penetration control.
- Reference and requirements for some specific materials are present in the installation standard, however the standard does not reference many materials that are in common use in construction (such as self adhesive membranes).
- Several of the figures illustrating air tightness concepts in the installation standard are inappropriate from a water penetration control perspective. An attempt should be made to illustrate details that will effectively perform all required functions along with the differences in installation technique that are required for different window and wall rain penetration and air leakage control strategies.

Proposed North American Fenestration Standard (NAFS)

- This standard, which is currently being developed, is intended to promote consistency throughout North America by presenting a unified approach for the various aspects of window performance. It has many of the strengths of CSA A440 and in addition it provides a framework that could be used to distinguish between more or less durable water penetration performance. The proposed standard also acknowledges the existence of project and site specific exposure conditions that may dictate product selection. The limitations of the NAFS are in many respects similar to those of CSA A440.

Recommendations

Codes

- Include consideration of micro-exposure or 'time of wetting' as an environmental design condition.
- Provide guidance on selection of water penetration control strategy for particular micro-exposure conditions.
- Mandate consideration and disclosure of design service lives for assemblies, components and materials used within the building envelope.
- Mandate the preparation of maintenance and renewals plans.

Manufacturing Standards

- Create a classification system for windows that reflects their water penetration control strategy.
- Relate window water penetration control strategy to micro-exposure conditions.
- Manufacturers should be mandated to provide maintenance and renewals requirements for their product.

Certification Program

- Requirement for installer training and certification.
- Periodic requirement for retest of products pulled randomly from the plant.

Installation Standards

- A separate section needs to be established that addresses rain penetration control.
- More guidance could be provided that relates specific methods of sub-sill drainage to varying exposure conditions.
- A requirement for testing of the window to wall interface and combination windows should be added to the current standard.
- Requirement for the manufacturer to produce shop drawings that fully detail these interfaces.
- Details should be included within the standard that illustrate sound fundamental concepts and principles for all functions that must be fulfilled by the window and window to wall interface.

Further Research

- Further research should be undertaken to better quantify 'time of wetness' for different overhang ratios, orientations, and geographic locations in Canada.
- There is a need to develop a 'Best Practice Guide' for windows that integrates all window performance criteria.

Related and Reference Documents

1. *Survey of Building Envelope Failures in the Coastal Climate of British Columbia*, Canada Mortgage and Housing Corporation, 1996.
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3. *Study of High-Rise Envelope Performance*, Canada Mortgage and Housing Corporation, 2001
4. *Glazing Design*, Canadian Building Digest No. 55, Division of Building Research, National Research Council, 1964
5. *Rain Leakage of Residential Windows in the Lower Mainland of British Columbia*, Building Practice Note No. 42, Division of Building Research, National Research Council of Canada, 1984.
6. *Rain Leakage in Wood Frame Walls: Two Case Histories*, Building Research Note No. 210, National Research Council of Canada, 1984
7. *Windows*, CSA Standard A440-00, Canadian Standards Association
8. *User Selection Guide to CSA A440-00*, Windows, Special Publication A440.1, Canadian Standards Association
9. *Window And Door Installation*, CSA Standard A440.4-98, Canadian Standards Association
10. *Water Penetration Resistance of Windows – Study of Manufacturing, Building Design, Installation and Maintenance Factors*, Canada Mortgage and Housing Corporation, 2003
11. National Research Council of Canada, National Building Code of Canada 1995
12. RDH Building Engineering Limited & Morrison Hershfield Limited, *Best Practice Guide – Wood Frame Envelopes In the Coastal Climate of British Columbia*, Canada Mortgage and Housing Corporation, 2001
13. *Guideline on Durability in Buildings*, S478-95, Canadian Standards Association
14. *North American Fenestration Standard – Voluntary Performance Specification for Windows, Skylights, and Glass Doors*, 2002

CMHC Project Manager: Silvio Plescia

Research Report: Water Penetration Resistance of Windows - Study of Codes, Standards, Testing and Certification

Research Consultant: RDH Building Engineering Limited, Vancouver, BC.

CMHC undertook this study in partnership with the Homeowner Protection Office and the British Columbia Housing Management Commission.

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Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Phone: 1 800 668-2642
Fax: 1 800 245-9274

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